CHALLENGES OF INTERNATIONAL PROGRAMS IN COMMERCIAL WIRELESS POWER 'TRANSMISSION

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ABSTRACT

The proposition is offered that only by forming international alliances will economically viable commercial wireless power transmission (WPT) result. Radio emissions from commercial WPT will. likely extend beyond the borders of a single nation. It is challenging to create a legitimate new service from the existing Radio Frequency Regulations. Because many nations participate in the International Telecommunications Union (ITU) process, the challenge is to devise means to incentivise them to yield frequency allocations for payloads and services as well as power transfer. International. demonstrations of WPT could aid in overcoming the challenging technical, environmental and economic skepticism. Multinational capital formation could possibly achieve the challenging magnitude of development funds required for WPT. Some proposed applications of WPT require equipment to be located around the Earth at the equator, thus involving many countries. The likely market size for a viable economic WPT enterprise must include many nations of the world.

INTRODUCTION

Proposed WPT commercial applications range in scope and altitude from Gigawatt Satellite Power Systems (SPS) [1] in Geosynchronous Earth Orbit (GEO), to low Earth orbit (LEO) to GEO space transportation [2] and down to circling aircraft [3] at high altitude in the Earth's atmosphere.

This paper presents the results of one phase of research carried out at the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration.

WPT applicati ons hold the promise of providing alternative ways of providing electric power, spa ce transportation and wide area communications. The power beam supported high altitude aircraft is an alternative to each country owning a GEO spacecraft. It is an alternative to fiber optics or other surace media linkage to every communications user in some countries. It could extend the diameter of a cellular communications cell to hundreds of km. The wrist mounted telephone may challenge the hand held units. However, there are many challenges that must be faced before such applications become reality.

In the spirit of fostering the incubation and development of "strategic partnerships" to pursue the commercial applications of wireless power technology (WPT) , I offer the proposition that only by forming international alliances will economj.tally viable activities result. The various challenges to WPT involve frequency allocation, selling the concepts, large capital formation, spreading of risk, geography issues and viable market size. All may involve international solutions that are discussed below. The first challenge is a key to commercialization of WPT.

THE FREQUENCIES CHALLENGE

Emissions resulting from WPT commercial activities are likely to extend beyond the borders of a single nation . Therefore, international cooperation is required in the needed allocation of spectrum to offer WPT service, particularly worldwide. In addition to the power transmission beam frequency and its harmonics [4], other RF frequencies are likely involved. Communications for command and control will be required. Revenue producing payloads such as broadcast or relay communications or radar transmission and reception will be necessary. Generally, these activities must be demonstrated to be not harmful or to not otherwise interfere with existing services. 'l'he engineering, analysis and testing for compliance are very expensive. One would like to perform the development and to conduct the required testing only once and at legitimate RF frequencies for payloads and services as well as power transfer.

The fear of not knowing if spectrum will be available leads to business risk. A "Catch-22" situation exists [5] similar to the problem of obtaining a job. You can't get a job unless you have experience, but you can't get experience

if you don't have a job. Wihout frequency allocations for WPT service,you can't demonstrate its benefits, and without a demonstration of benefits you can't get frequencies for the service.

Therefore, for other nations to permit utilization of commercial WPT, a challenge will be to foster the spectrum planning and frequency coordination that must be accomplished to define a new service.

The ITU exists as the forum for that function, handling International Radio Regulation extending currently up to 400 GHz. However, the challenge is to incentivise the activity. One could devise means that permit each potential user country to economically participate in the equipment development process as well as the spectrum planning. Then all may share in the revenue return on investment as well as the utilization of the product in the global marketplace.

The regulated microwave frequencies suitable for power beaming exist only as footnotes in the ITU Regulations at Industrial, Scientific or Medical (ISM) band center frequencies of 2.45, 5.8, 24.125, and 61.25 GHz. It is a pity that they are not harmonically related. It would make obtaining WPT services much easier, and reduce the challenging amount of filtering that must be engineered into such applications.

THE SELLING CHALLENGE

The concept of WPT is so far out of the scope of the normal range of knowledge that it is a difficult sell. Furthermore, people fear the unknown. The challenge is to develop a technical and economic legitimacy which could be aided by demonstrations and publicity in more than one nation.

A major selling challenge is safety. Microwaves contained in the oven are relatively benign, but microwave beams of high intensity are a threat to people, animals and other biota and equipment. Therefore, demonstrably safe beam power control systems are absolutely necessary. The engineering design of periodically self-testing beam intrusion detection and control systems will probably be mandatory [6] . The WPT systems must be designed to cope with the diversion, dimming or dousing of the energy beams that will be necessary to protect the populace and biota from harm. Batteries or other energy storage and techniques

such as a spare in the air may be needed to prevent system outages due to protective actions or weather outages. A further challenge will be to arrive at global standards for safety of emissions and susceptibility of equipment to permit system designs and assurance testing.

Participation in consortia can reduce the fear of a market ever materializing and the fear of being left out of a potential large market. WPT technology depends upon the laws of physics, but WPT economics depends upon the laws of the global marketplace. Each country wants to maintain technologies critical to its security and to promote industrial competitiveness, hence laws against technology transfer such as the International Traffic in Arms Regulations (ITAR) of the US State Department and the Export Administration Regulations (EAR) of the US Commerce Department. A challenge is how to devise protection against such technology transfer while assuring rational engineering interfaces for such a complex system.

The benefits of WPT must be quantified and presented not only as a new way of doing things, but also as a better substitute for some things that are ongoing that are less desirable, such as coal burning. Can coal miners be retrained to produce solar cell arrays? Are people inside aircraft flying through power beams at less of a hazard than breathing smog? Will acid rain hasten aluminum skin deteoriation? Is there a need for reusable WPT LEO-GEO transport now? Can a switchboard in the sky be realized in a near stationary microwave beam powered aircraft, helicopter or aerostat? Is there a market need for a personal communication device? Should the National Aeronautics and Space Administration who used taxpayer dollars to develop the rectenna technology be pursuing it further? What return on investment should the taxpayers expect? Will wrist mounted telephones result in less battery mass disposed in the environment than pocket phones?
These are some "food for thought" challenging questions that need study and answers from the recognized authori.ties.

A suggestion for SPS development is to devise ways for each voting nation to economically or beneficially obtain sharing of the fruits of SPS, whether or not they receive electric power from it. Perhaps they get paid for operating it, or maintaining it, protecting it, upgrading it, doing billing for it, providing insurance for it, providing investment capital in return for profit sharing, monitoring performance of it, pay for selling power from it to others,

pay for providing tours of it, given retainers for resolving litigation concerning it, earning fees for promoting additional. uses of it, etc.

THE CAPITAL CRITICAL MASS CHALLENGE

In addition to appearing so revolutionary to new investors, commercial applications of WPT are so capital intensive that it is difficult for a single nation to pull together the critical mass required for the development price. Such a challenge fosters an international consortium. Current estimates for the development costs of Satellite Power Systems are several hundreds of Billions of dollars. The development costs for a LEO to GEO electric transport system are less, but probably several Billions of dollars. The much less development cost for demonstrating a fully qualified, electromagnetically compatible high altitude platform electric powered airplane are in the several hundreds of Millions of dollars. The magitude of the capital required along with the development risk is such that probably only a multinational approach is viable at this state of WPT awareness. Particularly given the current economic worldwide conditions.

Perhaps some existing international consortia such as Intelsat, Inmarsat *or* Iridium might take on high altitude platform aircraft as a junior department. Could the new Local Multipoint Distribution Service (LMDS) be utilized on the WPT supported platforms?

THE GEOMETRY CHALLENGE

Some proposed WPT applications require use of several equatorial land mass locations spread around the globe. No single nation can meet that challenge. For example, the United States has only jurisdiction over Jarvis Island south of Hawaii and half a degree below the equator. Some South American countries, African countries, other Pacific Islands and Indonesia are the only nations with near-equator lands. International cooperation will be mandatory for such service. Also, GEO WPT Applications such as SPS are obviously visible from more than one country.

THE WORLD MARKET CHALLENGE

The likely market size for a viable economic enterprise must include many nations of the World. To produce adequate return on investment for many WPT activities will require a market that is larger than just a single country. For example, there are currently 186 nations in the World [7]. As many as 156 could be served by only one high altitude electric aircraft maintained aloft by a microwave power beam from each individual country. Their own geostationary radio and TV broadcast and relay platform, with a geometric horizon from an altitude of 18.3 km (60,000 ft, 11.4 mi) of 960 km (600 mi) diameter. The land area of the Earth is 148,429,000 sq km, only slightly over 200 aircraft at 60,000 ft altitude could on average cover the Earth's land mass for communication purposes.

The expected economic return from any individual. country of small area would probably not be adequate for raising the several hundred Million dollar development effort if they tried to do it alone. Yet if they could participate in the development for an international service, they could reap the benefits at a much lower investment cost .

There are at least 30 countries that could use more than one platform. For example, almost 14 would be needed to go in a single string across northern Russia. 6 each to traverse China or Indonesia, 5 for Brazil, 4 each for the **USA,** Canada, Australia, Argentina and Chile., etc.

CONCLUSIONS

There are many challenges to WPT commercialization which may be met with international cooperation. Radio spectrum allocations require the international ITU participate on. The selling of WPT could be aided by demonstrations of the technology and beam power safety assurance in many countries and the development of international safety standards for biota and equipment. International consortia will be required to raise the tremendous capital investments that WPT will require. The very nature of some WPT applications requires multination participation because of the geometry of the system. And finally, a world wide market may likely be necessary for viable economic commercial WPT activities.

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